Attorney's Docket No.: 06618-379002 / CIT 2898-C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Sarath Gunapala et al.
Serial No.: 09/924,209
Filed : August 7, 2001
Title : QUANTUM WELL SENSOR HAVING SPATIALLY SEPARATED SENSING COLUMNS (AS AMENDED)

Art Unit : 2815
Examiner : Baumeister, B.
Confirmation No.: 1843

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

APPEAL BRIEF

Applicants herewith file this appeal brief under rule 37 CFR 41.37, thereby perfecting the notice of appeal 37 CFR 41.31 which was originally filed on Feburary 17, 2005. The sections required by rule 37 CFR 41.37 follow.

(1) Real Party in Interest

California Institute of Technology is the assignee of this application and is the real party in interest.

(2) Related Appeals and Interferences

There are no known related appeals and/or interferences.

CERTIFICATE OF MAILING BY EXPRESS MAIL

Express Mail Label No. EV 471536328 US

September 19, 2005
Date of Deposit

(3) Status of Claims

Claims 1-11 are pending and under consideration on their merits. Each of Claims 1-11 is rejected. The rejection of each of Claims 1-11 is appealed.

(4) Status of Amendments

An amendment with an RCE was filed on June 28, 2004. This amendment was apparently entered and considered based on the content of the Office Action dated September 17, 2004.

In addition, Applicants concurrently file an amendment to the drawings in response to the rejections to FIGS. 3-6 stated in the Office Action dated September 17, 2004.

(5) Summary of Claimed Subject Matter

Claims 1 and 6 are the only two independent claims in Claims 1-11 that are pending in this case and are directed to quantum-well semiconductor devices as supported by examples shown in FIGS. 1 and 3 and described in the original specification. Such devices include quantum-well structures that are arranged in columnar shapes and spatially separated from one another by a gap.

Claim 1

Claim 1 specifically recites a quantum-well semiconductor device as supported by the device in FIGS. 1 and 3 that senses radiation energy. The device recited in Claim 1 includes a substrate as supported by the structure 102, and a plurality of quantum-well structures as supported by the structure 110

arranged in columnar shapes and spatially separated from one another by a gap as supported by the structure 120. The substrate is made of a substantially transparent semiconductor material. The gap 120 is electrically insulating and may be an air gap or filled with a dielectric material. The quantum-well structures 110 are formed over the substrate 102 to form a periodic array as an optical grating to optically diffract light at a wavelength absorbed by the quantum-well structures 110.

Claim 1 further recites that each quantum-well structure 110 includes, a first conductive contact layer as supported by the structure 112 formed over the substrate 102, a quantum-well stack as supported by the structure 114 having a plurality of alternating quantum-well layers formed in parallel over said first conductive contact layer 112 and operating to absorb radiation polarized perpendicularly to the quantum-well layers, and a second conductive contact layer as supported by the structure 112 formed over the quantum-well stack 114. In addition, each quantum-well layer in each quantum-well structure 110 is continuous without a void and each quantum-well structure 110 has opposing parallel side walls perpendicular to the substrate 102 to form an optical cavity therebetween in resonance with the wavelength.

<u>Claim 6</u>

Claim 6 also recites a quantum-well semiconductor device as supported by FIGS. 1 and 3 to include a substrate of a substantially transparent semiconductor material (e.g., 102), and quantum-well structures in columnar shapes (e.g., 110) formed over the substrate 102. The quantum-well structures 110 form a periodic array to effectuate an optical grating which diffracts light to have a component polarization perpendicular to the substrate 102, and are spatially separated from one another by a gap 120 which is electrically insulating. Each quantum-well structure 110 has opposing parallel side walls perpendicular to the substrate 102 to form an optical cavity therebetween. Each quantum-well structure 110 includes, a first conductive contact layer 112 formed over the substrate 102, a quantum-well stack 114 having a plurality of quantum-well layers formed in parallel over the first conductive contact layer 112 to absorb radiation polarized perpendicularly to the quantum-well layers, and a second conductive contact layer 116 formed over the quantum-well stack.

(6) Grounds of Rejection

1. Are Claims 1-3, 5-8, and 10 unpatentable under 35 USC 103(a) over Choi '015 in view of Chen?

2. Are Claims 4, 9, and 11 are unpatentable under 35 USC 103(a) over Choi'015 in view of Chen and further in view of Choi '469?

(7) Argument

7.1. Claims 1-3, 5-8, and 10 are distinctly patentable under 35 USC 103(a) over Choi '015 in view of Chen

Claims 1-3, 5-8, and 10 stand rejected under 35 USC 103(a) over Choi '015 in view of Chen. Applicants respectfully traverse because the alleged combination of Choi '015 and Chen fails to teach each claimed feature and because the alleged combination of Choi '015 and Chen cannot be properly made under 35 USC 103(a).

7.1.1 The alleged combination of Choi '015 and Chen fails to teach each claimed feature

The Patent Office contends that the combination of the empty cavities 251 and quantum-well stacks S with straight walls in FIGS. 5, 6, and 9 in Choi '015 and the 2D cross grids and the suggestion of various sidewall profiles created by wet chemical etching or dry etching in Chen teaches each of the claimed features in Claims 1-3, 5-8, and 10. This contention is not supported by the disclosures of Choi '015 and Chen.

First, Claims 1-3, 5-8, and 10 recite a plurality of quantum-well structures, arranged in columnar shapes and spatially separated from one another by a gap which is electrically insulating and state that each quantum-well structure has opposing parallel side walls perpendicular to said substrate. Notably, the recited quantum-well structures form an optical grating. As well understood in optics, the quantum-well

structures are optically coupled together as a whole in order to form the optical grating. In the present claims, the quantum-well structures, optically coupled together as a whole, diffract received light to have polarization components that are perpendicular to the quantum well layers and the substrate in order to be absorbed by the quantum-well structures.

In contrast, the alleged combination of Choi '015 and Chen uses separated optical elements individually, without optical coupling with each other, to redirect light. The described separated optical elements do not form an optical grating.

For example, in the devices shown in FIGS. 5, 6, and 9 of Choi '015 that are specifically cited by the Patent Office, Choi '015 provides the following:

> Cavities 251 are sized so that each one will function ***as an independent single-slit diffraction unit***. Specifically, if the width of cavity 251 is in the order of a small number of wavelengths of IR radiation R1, single-slit diffraction of IR radiation R1 at cavity 251 will take place, causing IR radiation R1 to break up and bend into a continuum of radiation components, e.g., radiation components R7, R8 and R9, directed at different angles most of which will be significantly closer to the desired plane in which absorption takes place. (emphasis added)

Col. 6, line 59-Col. 7, line 1.

Apparently, according to the teaching in Choi '015, independent single-slit diffraction units diffract light in order to crate radiation components that have components perpendicular to the quantum-well layers, thus increasing the absorption efficiency of the detector. Nothing in Choi '015,

however, suggests anything on configuring the cavities 251 to be optically coupled to form an optical grating.

The teaching of an independent single-slit diffraction unit in Choi '015 specifically *teaches away* from the recited formation of the optical grating by the quantum-well structures in the present claims because the cavities 251 in Choi '015 are, in the words of Choi '015, independent. In this regard, Choi '015 specifically makes the width of cavity 251 greater than the IR wavelength to be absorbed so that there cannot be optical coupling between adjacent cavities 251 in order to form independent single-slit diffraction units.

Chen also specifically *teaches away* from the recited optical grating formed by quantum-well structures in the present claims. More specifically, Chen teaches the use of the corrugation shown in Fig. 1(c) to redirect normal incident light by the single slit diffraction and the corrugation shown in Fig. 1(b) to redirect normal incident light by the total internal reflection (TIR) from the slanted surfaces (Column 1, page 1432). These two optical mechanisms are distinctly different from the recited optical grating formed by the quantum-well structures of the present claims. In fact, the Patent Office fails to find any description in Chen suggesting that corrugation structure and the slanted surfaces are optically configured as an optical grating.

Therefore, the alleged combination of Choi '015 and Chen fail to disclose the present invention. For this reason alone, Claims 1-3, 5-8, and 10 are patentable.

Second, Claims 1-3, 5-8, and 10 recite that each quantum-well structure has opposing parallel side walls perpendicular to the substrate and forms an optical cavity. As illustrated in

FIG. 1 of this application, this recited optical cavity is a solid column formed by the quantum well layers and the surrounding gaps. For example, in Claim 1, the optical cavity is "in resonance with the wavelength" absorbed by the recited quantum-well structures. The alleged combination of Choi '015 and Chen fails to disclose this recited feature of the present claims.

In this regard, Choi '015 discloses cavities 251 with straight walls in stack S of quantum well layers of QGIP 220 (FIGS. 5, 6, 7, and 8). Although, the term "cavity" is used in Choi '015, the cavities 251 are in fact voids formed in the quantum well layers. Hence, inside each cavity 251, there are no light-absorbing quantum well layers. As such, each cavity 251 does not absorb light. Therefore, the cavity 251 is different from the recited optical cavity in the present invention.

In addition, the cavities 251 in Choi '015 are sized as independent single-slit diffraction units to diffract input light with normal incidence to allow for absorption by the quantum well layers in the stack S. Notably, the light-absorbing stack S is contiguous with embedded cavities 251 (FIG. 6) and thus is entirely different from the recited separated columnar quantum-well structures that form separate optical cavities in the present invention. As a comparison, the structural pattern in FIG. 6 of Choi '015 may be viewed as a photographic negative of the columnar quantum-well structures of the present invention to a certain extent.

Chen, although very different from Choi '015, also completely lacks any disclosure on this aspect of the present invention. Chen describes corrugations with slanted side

surfaces. In Chen's 1D and 2D designs, such opposing slanted surfaces, by virtue of their physical designs, cannot form optical cavities of the present invention. In fact, Chen specifically teaches that a normal incident light ray is bounced between different slanted surfaces of different corrugations multiple times with a thinned substrate (Fig. 2). Therefore, Chen's design does not confine light between two opposing surfaces as the optical cavity of the present invention. To the contrary, Chen's design relies on the slanted surfaces which cannot confine light as configured in Chen's design.

Moreover, Chen's design is configured in such a way that the light coupling efficiency is "free of detection wavelength dependence and pixel size dependence" (Column 2, page 1431).

In stark contrast, the optical cavity of the present invention has a specific resonance wavelength at which the absorption of light occurs in the quantum-well layers. Notably, each columnar quantum-well structure is made, e.g., by the dimension and material indices, to be in resonance with the wavelength to be absorbed. Therefore, Chen's design *teaches away* from the present invention.

In view of the above, the alleged combination of Choi '015 and Chen fails to disclose several features recited in Claims 1-3, 5-8, and 10. Therefore, Claims 1-3, 5-8, and 10 are patentable.

7.1.2. The alleged combination of Choi '015 and Chen cannot be properly made under 35 USC 103(a)

Independent from the above arguments, Claims 1-3, 5-8, and 10 are patentable also because the alleged combination of Choi

'015 and Chen cannot be properly made under 35 USC 103(a) for lack of the motivation or suggestion to combine.

Choi '015 describes void cavities in the quantum-well layers as independent single-slit diffraction units to diffract light and to create light field components perpendicular to the quantum well layers. Chen discloses slanted surfaces to achieve light field components perpendicular to the quantum well layers by reflection. These two approaches are technically very different and nothing in Choi '015 and Chen suggests any motivation to combine in the way suggested by the Patent Office. The Patent Office has not provided any other evidence outside the two cited references to show the motivation to combine. Therefore, the two references cannot be combined to support the rejections to the current claims. As such, the rejections should be withdrawn.

Notably, the teaching in Chen ***specifically negates*** the contended combination by the Patent Office.

As discussed above, Chen uses properly slanted surfaces of corrugations in the quantum well structures to direct normal incident light through total internal reflection (TIR) so that the light coupling efficiency is "free of detection wavelength dependence and pixel size dependence" (Column 2, page 1431). In Column 1, page 1432, Chen states that

> *The **essential idea** of the C-QWIP is **to create a maximum number of slanted sidewalls** within the detector active region to channel normal incident light into the parallel direction.*

As described in Chen, the ideal slanted surfaces may be at 45 degrees as used in the edge coupling detectors (Column 2, page 1431 and column 1, page 1433).

However, due to the wet etching used in Chen, the V grooves are defined and controlled by the crystallographic directions of the quantum well structures and can only form 50-degree slanted surfaces along one of the two orthogonal crystallographic directions. In the orthogonal crystallographic direction, an inverted V groove with a slanting angle of 70 degrees is formed. Unfortunately, the inverted V grooves reflect light away from the light-absorbing quantum-well region and thus degrade the detector performance (but they reduce the dark current).

In the above context, Chen concludes that further investigation is needed on various sidewall profiles created either by wet chemical etching or by dry etching to fully explore the potential of the C-QWIP (Column 2, page 1436).

In Chen, the essential idea of the C-QWIP is to create a maximum number of slanted sidewalls within the detector active region to channel normal incident light into the parallel direction. Therefore, Chen's suggestion on "various sidewall profiles" are various "slanted" sidewalls, such as the slanted sidewalls at 45 degrees and removal of the inverted V grooves. U.S. Patent No. 6,545,289 to Gunapala and other two co-applicants of this application, which has been made of record in this case by applicants, provides a solution to this problem caused by the natural crystallographic directions.

The Patent Office completely ignores this use of the total internal reflection (TIR) of slanted surfaces as the essential idea for the C-QWIP in Chen by alleging that straight sidewall profiles in Choi '015 may be combined with Chen's structure.

This assertion by the Patent Office contradicts Chen's own teaching for the slanted surfaces as the essential idea for the C-QWIP.

Based on the above, the Patent Office fails to make a prima facie showing of the motivation or suggestion for the contended combination and accordingly the combination is improper under 35 USC 103(a).

7.1.3. The alleged combination of Choi '015 and Chen are based on hindsight

In view of the lack of any support from the disclosures in Choi '015 and Chen and any support from other evidence, the Patent Office has apparently made the alleged combination based on hindsight after having the benefit of the disclosure of the present invention. Under 35 USC 103(a), the rejections cannot stand and must be withdrawn.

7.2 Claims 4, 9, and 11 are distinctly patentable under 35 USC 103(a) over Choi'015 in view of Chen and further in view of Choi '469

Claims 4, 9, and 11 are also patentable over Choi'015/Chen and further in view of Choi '469 based on at least the above arguments. Choi '469 teaches multi-color quantum well detectors and the use of a transparent substrate 21 with an angled side surface 22 at 45 degrees to receive input light in order to cause optical absorption in the quantum-well layers 24. Notably, Choi '469 does not cure the defects in the combined teaching of Choi '015 and Chen as discussed above. As such,

Claims 4, 9, and 11 are distinctly different from the combined teaching Choi'015, Chen and Choi '469 and thus are patentable.

In summary, Claims 1-11 are patentable over the cited prior art and should be in full condition for allowance. A formal notice to that effect is respectfully solicited.

Please apply the brief fee of $250.00 and any other charges or credits to Deposit Account No. 06-1050.

Respectfully submitted,

Date: September 19, 2005

Scott C. Harris
Reg. No. 32,030

By Bing Ai
Reg. No. 43,312

Fish & Richardson P.C.
PTO Customer No. 20985
12390 El Camino Real
San Diego, California 92130
Telephone: (858) 678-5070
Facsimile: (858) 678-5099

10552988.doc

Appendix of Claims

1. A quantum-well semiconductor device that senses radiation energy, comprising:

a substrate of a substantially transparent semiconductor material; and

a plurality of quantum-well structures, arranged in columnar shapes and spatially separated from one another by a gap which is electrically insulating, said plurality of quantum-well structures formed over said substrate to form a periodic array as an optical grating to optically diffract light at a wavelength absorbed by said plurality of quantum-well structures,

wherein each quantum-well structure includes, a first conductive contact layer formed over said substrate, a quantum-well stack having a plurality of alternating quantum-well layers formed in parallel over said first conductive contact layer and operating to absorb radiation polarized perpendicularly to said quantum-well layers, and a second conductive contact layer formed over said quantum-well stack, and wherein each quantum-well layer in each quantum-well structure is continuous without a void and each quantum-well structure has opposing parallel side walls perpendicular to said substrate to form an optical cavity therebetween in resonance with the wavelength.

2. The device as in claim 1, further comprising a plurality of separate metallic elements respectively formed over said plurality of quantum-well structures.

3. The device as in claim 1, wherein dimensions and indices of said plurality of quantum-well structures and respective gaps are configured to make said optical cavity in a resonance condition so that a magnitude of received radiation having a polarization perpendicular to said quantum-well layers is greater than a magnitude of received radiation having a polarization perpendicular to said quantum-well layers when the resonance condition is not met.

4. The device as in claim 1, wherein each quantum-well structure includes at least two different stacks of quantum-well layers which respectively absorb light at two different wavelengths.

5. The device as in claim 1, wherein gaps between adjacent quantum-well structures include a dielectric insulator that has an index of refraction less than an index of refraction of each quantum-well structure.

6. A quantum-well semiconductor device that senses radiation energy, comprising:

a substrate of a substantially transparent semiconductor material; and

a plurality of quantum-well structures in columnar shapes formed over said substrate to form a periodic array to effectuate an optical grating which diffracts light to have a component polarization perpendicular to the substrate, and spatially separated from one another by a gap which is electrically insulating, wherein each quantum-well structure has opposing parallel side walls perpendicular to said substrate to form an optical cavity therebetween,

wherein each quantum-well structure includes, a first conductive contact layer formed over said substrate, a quantum-well stack having a plurality of quantum-well layers formed in parallel over said first conductive contact layer to absorb radiation polarized perpendicularly to said quantum-well layers, and a second conductive contact layer formed over said quantum-well stack.

7. The device as in claim 6, further comprising a plurality of separate metallic elements respectively formed over said plurality of quantum-well structures.

8. The device as in claim 6, wherein dimensions and indices of said plurality of quantum-well structures and respective gaps are configured to make said optical cavity in a resonance condition so that a magnitude of received radiation having a polarization perpendicular to said quantum-well layers is greater than a magnitude of received radiation having a polarization perpendicular to said quantum-well layers when the resonance condition is not met.

9. The device as in claim 6, wherein each quantum-well structure includes at least two different stacks of quantum-well layers which respectively absorb light at two different wavelengths.

10. The device as in claim 6, wherein gaps between adjacent quantum-well structures include a dielectric insulator that has an index of refraction less than an index of refraction of each quantum-well structure, and wherein dimensions of each quantum-well structure are configured to form an optical cavity between

two opposing side-wall surfaces in said each quantum-well structure with a resonance at a wavelength of absorbed light.

11. The device as in claim 6, wherein each quantum-well structure further includes quantum well layers formed between said first conductive contact layer and said second conductive contact layer to absorb light at a wavelength different from a wavelength of light absorbed by said quantum-well stack.